

State of New Jersey  
James E. McGreevey, Governor

# 2002 FISH IBI REPORT

Volume 1 of 2



New Jersey Department of Environmental Protection  
Bradley M. Campbell, Commissioner

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**April 2004**

# **2002 FISH IBI REPORT**

Volume 1 of 2

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# EXECUTIVE SUMMARY

Historically, the health of aquatic systems was monitored primarily through chemical means. However, chemical monitoring provides only a “snapshot” of conditions at the time of sampling and may fail to detect acute pollution events (e.g., runoff from heavy rain, spills), non-chemical pollution (e.g., habitat alteration) and non-point source pollution.

In order to address the limitations of chemical monitoring, DEP supplements chemical monitoring with biological monitoring which is based on the premise that biological communities are shaped by the long-term conditions of their environment and more accurately reflect the health of an ecosystem. Currently, the Bureau of Freshwater and Biological Monitoring (BFBM), within the Water Monitoring and Standards program, monitors benthic macroinvertebrate assemblages (insects, worms, clams, etc.) at over 800 stream stations throughout New Jersey.

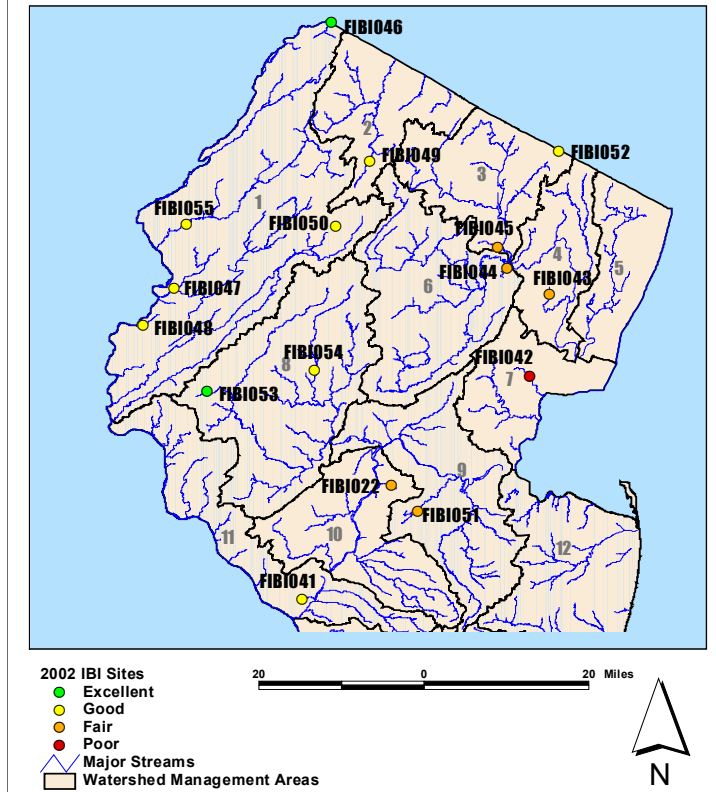
Benthic macroinvertebrate assemblages are generally reflective of short-term and local impairment. In order to assess environmental conditions on a larger spatial and temporal scale, BFBM began to supplement benthic macroinvertebrate monitoring with an index of biotic integrity (IBI) during summer 2000. An IBI is an index that measures the health of a stream based on multiple attributes of the resident fish assemblage. Each site sampled is scored based on its deviation from reference conditions (i.e., what would be found in an unimpacted stream) and classified as “poor”, “fair”, “good” or “excellent”. In addition, habitat is evaluated at each site and classified as “poor”, “marginal”, “suboptimal” or “optimal”.

Data provided by the IBI are becoming another component of the DEP's suite of environmental indicators. The data will help to measure water quality use attainment and the Department's success in attaining the Clean Water Act goal of “fishable” waters as elaborated in the New Jersey Integrated Water Quality Monitoring and Assessment Report. IBI data will also be used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. Additionally, efforts from the new stormwater rules may be reflected in future IBI sampling results. Currently, IBI data collected from northern New Jersey are used in an approach to nominate candidate waters for upgrade to a Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

In 2002, the third year of sampling, 16 of the 20 planned sites were sampled before the drought forced an early conclusion to the sampling season. Two sites were rated “excellent”, eight were “good”, five were “fair” and one was “poor”. The Elizabeth River at North Avenue (FIBI042) is the first IBI site to receive a poor rating. More information on specific water quality impairments at this site (station ID ELI-2) can be found in the “New Jersey 2002 Integrated Water Quality Monitoring and Assessment Report” ([www.state.nj.us/dep/wmm/sqwgt/wat/index.html](http://www.state.nj.us/dep/wmm/sqwgt/wat/index.html))

It is anticipated that by summer 2004, the IBI network will have approximately 100 stations in northern New Jersey. Stations will be visited once every five years as part of the BFBM's monitoring efforts. Indices for streams in southern New Jersey and headwater streams in northern New Jersey are currently being evaluated.

## 2002 IBI Sites



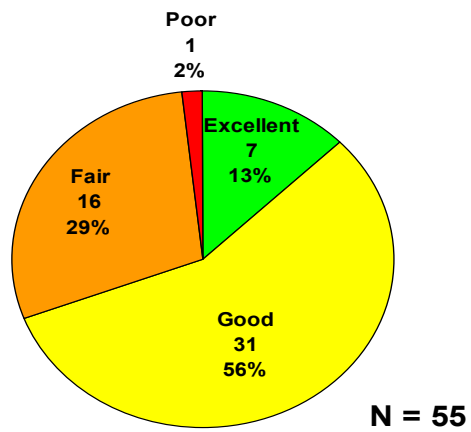
## 2002 IBI RESULTS<sup>1,2</sup>

FIBI Site	Waterbody	County	Habitat Rating	IBI Score	IBI Rating	
FIBI022	Six Mile Run	Somerset	Suboptimal	36	Fair	Orange circle
FIBI041	Shabakunk Creek	Mercer	Suboptimal	38	Good	Yellow circle
FIBI042	Elizabeth River	Union	Marginal	26	Poor	Red circle
FIBI043	Third River	Essex	Marginal	36	Fair	Orange circle
FIBI044	Deepavaal Brook	Essex	Marginal	36	Fair	Orange circle
FIBI045	Beaver Dam Brook	Morris	Marginal	32	Fair	Orange circle
FIBI046	Clove Brook	Sussex	Optimal	46	Excellent	Green circle
FIBI047	Beaver Brook	Warren	Optimal	40	Good	Yellow circle
FIBI048	Buckhorn Creek	Warren	Optimal	40	Good	Yellow circle
FIBI049	Walkill River	Sussex	Suboptimal	40	Good	Yellow circle
FIBI050	Lubbers Run	Sussex	Suboptimal	44	Good	Yellow circle
FIBI051	Ireland Brook	Middlesex	Suboptimal	36	Fair	Orange circle
FIBI052	Ramapo River	Bergen	Suboptimal	38	Good	Yellow circle
FIBI053	Mulhockaway Creek	Hunterdon	Suboptimal	46	Excellent	Green circle
FIBI054	Lamington River	Hunterdon	Optimal	40	Good	Yellow circle
FIBI055	Paulins Kill	Warren	Suboptimal	42	Good	Yellow circle

<sup>1</sup>Due to severe drought conditions at the end of the sampling season, only 16 sites were sampled. Additional sites will be added in 2003.

<sup>2</sup>Sampling maps and data for each site may be found in Volume 2 of this report.

## IBI Ratings - 2000-02



Summary of 1st round IBI ratings to date for 55 sites in northern New Jersey. It is anticipated that approximately 100 sites will be sampled by the end of the 1st Round (Summer 2004).

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## INTRODUCTION

Monitoring the health of aquatic systems is a critical component of watershed management. Historically, aquatic systems were monitored primarily through chemical means. Unfortunately, chemical monitoring provides only a “snapshot” of conditions at the time of sampling and may fail to detect acute pollution events (e.g. runoff from heavy rain, spills) and non-chemical pollution (e.g. habitat alteration). In order to address the shortcomings of chemical monitoring, the New Jersey Department of Environmental Protection supplements chemical monitoring with biological monitoring. Biological monitoring is based on the premise that biological communities are shaped by the long-term conditions of their environment and more accurately reflect the health of an ecosystem.

The monitoring of stream fish assemblages is an integral component of many water quality management programs for a variety of reasons (See Table 1), and its importance is reflected in the aquatic life use support designations adopted by many states. Narrative expressions such as "maintaining coldwater fisheries", "fishable", or "fish propagation" are prevalent in many state standards. In New Jersey, surface water quality criteria are closely aligned with descriptors such as *trout production*, *trout maintenance* and *non-trout* waterways. Fish assemblages can be stand alone indicators of a waterbody's health and/or fishability. In addition, they may be combined with other biological and chemical indicators to assist in the nomination of waters for upgrade to Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

The general methodology currently employed in the compilation of these studies and reports is the Rapid Bioassessment Protocol described in Barbour et al. (1999) with some modifications for regional conditions (Kurtenbach 1994). The principal evaluation mechanism utilizes the technical framework of the *Index of Biotic Integrity (IBI)*, a fish assemblage approach developed by Karr (1981). The IBI incorporates the zoogeographic, ecosystem, community and population aspects of the fish assemblage into a single ecologically based index. Calculation and interpretation of the IBI involves a sequence of activities including: fish sample collection, data tabulation, and regional modification<sup>1</sup> and calibration of metrics and expectation values. This concept has provided the overall multimetric index framework for rapid bioassessment in this document.

Data provided by the IBI are becoming another component of the DEP's suite of environmental indicators. The data help to measure water quality use attainment and the Department's success in attaining the Clean Water Act goal of "fishable" waters as elaborated in the New Jersey Integrated Water Quality Monitoring and Assessment Report. IBI data will also be used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the state's freshwater fish assemblages. Currently, IBI data collected from northern New Jersey are used in an approach to nominate candidate waters for upgrade to a Category One antidegradation classification (NJAC 7:9B) based on exceptional ecological significance.

**TABLE 1**

**ADVANTAGES OF USING FISH AS INDICATORS OF ENVIRONMENTAL HEALTH**

1. Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile (Karr et al. 1986).
2. Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores). They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.
3. Fish are at the top of the aquatic food chain and are consumed by humans, making them important subjects in assessing contamination.
4. Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field and released unharmed.
  - Environmental requirements of common fish are comparatively well known.
  - Life history information is extensive for most species.
  - Information on fish distributions is commonly available.
5. Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (e.g. coldwater, coolwater, warmwater, sport, forage).
  - Monitoring fish assemblages provides direct evaluation of "fishability", which emphasizes the importance of fish to anglers and commercial fisherman.
6. Fish account for nearly half of the endangered vertebrate species and subspecies in the United States (Warren and Burr 1994).

**FIELD COLLECTION PROCEDURES**

Primary objectives of the fish collections are to obtain samples with representative species and abundances, at a reasonable level of effort. Sampling effort is standardized by using similar stream lengths, collection methods, and habitat types. Stream segments selected for sampling must have a minimum of one riffle, run, and pool sequence to be considered representative.

**TABLE 2****REQUIREMENTS FOR FISH SAMPLING BASED ON STREAM SIZE**

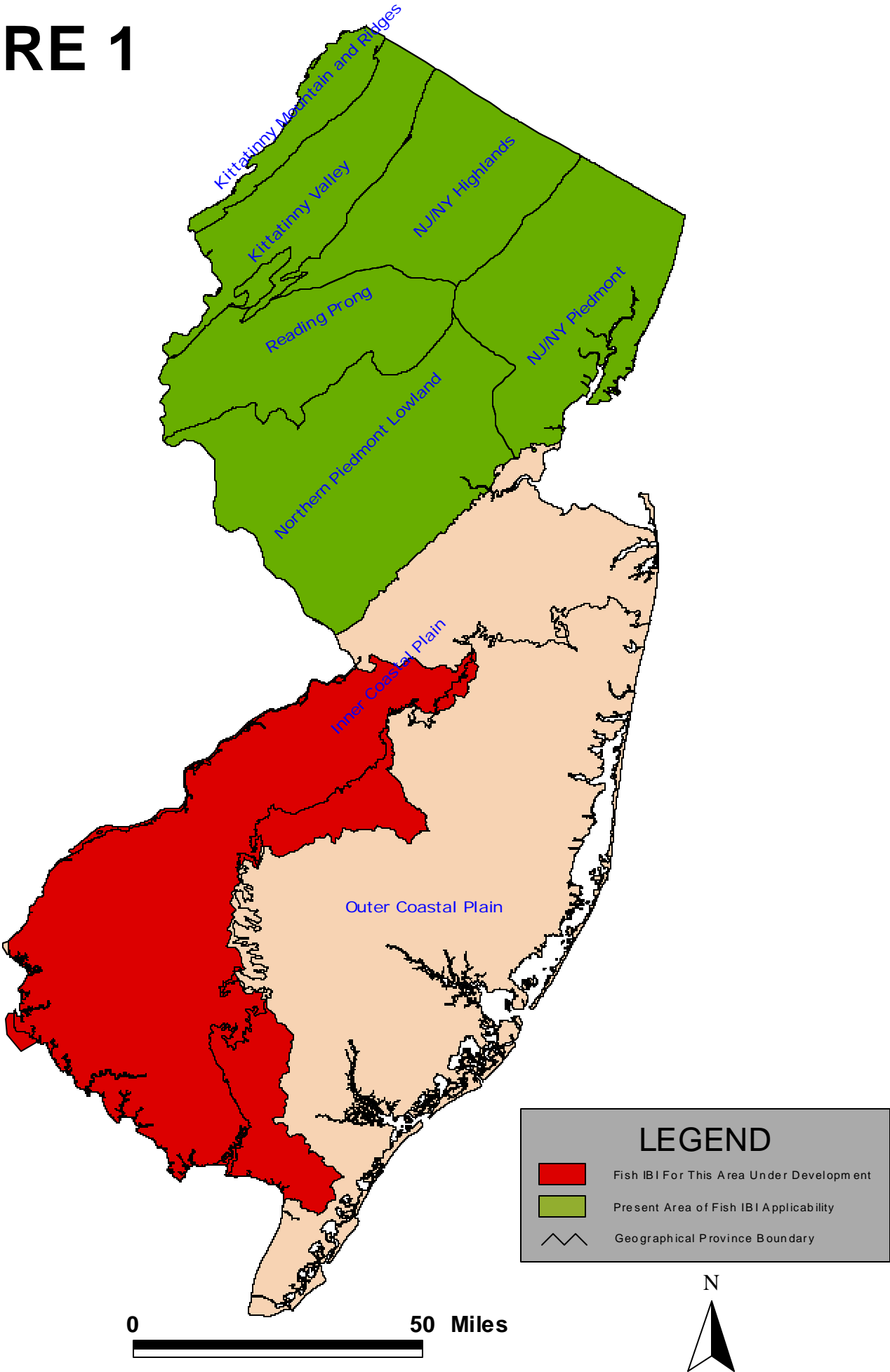
	<b>A</b>	<b>B</b>	<b>C</b>
Stream Size	Moderate to large streams and rivers (5 <sup>th</sup> order or greater)	Wadeable streams (3 <sup>rd</sup> and 4 <sup>th</sup> order)	Headwater streams (1 <sup>st</sup> and 2 <sup>nd</sup> order)
Sampling Distance (meters)	500 m	150 m	150 m
Electrofishing Gear	12' boat	2 Backpacks or barge electrofishing unit	1-2 Backpack electrofisher(s)
Power Source	5000 watt generator	24 volt battery or 2500 watt generator	24 volt battery

Streams with drainage areas less than 5 square miles are presently excluded from IBI scoring because of naturally occurring low species richness. Often streams classified as trout production waters fall into this category. More appropriate assessment methods for these streams include the measurement of trout abundance and/or young of the year production. Benthic macroinvertebrate assessments are also a viable alternative. In addition, atypical habitats such as dams and mouths of tributaries are avoided, unless the intent of the study is to determine the influence these habitats have on the fish assemblage. Most often, sampling atypical habitats results in the collection of fish species not represented in typical stream reaches. Sampling intermittent streams should also be avoided. These streams require the development of a separate set of IBI scoring criteria.

Fish are sampled primarily with electrofishing gear using pulsed direct current (DC) output. This method of collection has proved to be the most comprehensive and effective single method for collecting stream fishes. Direct current is safer, more effective, especially in turbid water, and less harmful to the fish. In waters with low conductivity (less than 75  $\mu\text{mhos/cm}$ ) it may be necessary to use an AC unit (Lyons 1992). Selection of the appropriate electrofishing gear is dependent on stream size (Table 2). A typical sampling crew consists of four to seven people (Fig. 2), depending on the gear being utilized. A minimum of two people are required for netting the stunned fish. Electrofishing is conducted by working slowly upstream for 150 meters and placing the electrodes in all available fish habitat. Stunned fish are netted at and below the electrodes as they drift downstream. Netters attempt to capture fish representing all size classes. All fish captured are immediately placed in water filled containers strategically located along the stream bank in order to reduce fish mortality.

<sup>1</sup> The IBI methodology presently being used in these studies was modified from Plafkin et al. (1989) to meet the regional conditions of New Jersey (not all of the state, however, is covered, see Fig. 1) based on work by Kurtenbach (1994). It should be noted, however, that an enumeration of fish assemblages, regardless of whether an IBI is calculated or not, is still a useful *environmental indicator* capable of providing stand alone information to determine whether the affected stream(s) are capable of meeting the narrative criteria of "fishable".

FIGURE 1



**FIGURE 2**

**TYPICAL ELECTROSHOCKING OPERATION**



Sampling time generally requires 1.5 to 2 hours per station. This includes the measurement of chemical and physical parameters. Sampling is conducted during daylight hours, June through early October, under normal or low flows, and never under atypical conditions such as high flows or excessive turbidity caused by heavy precipitation. Fish collections made in the summer and early fall are easier, safer and less likely to disturb spawning fish.

**SAMPLE PROCESSING**

Fish are identified to the species level, counted, examined for disease and anomalies, measured (game fish), released and recorded on fish data sheets in the field. The sampling protocol employed is ineffective in capturing a representative sample of smaller fish because they are difficult to see and tend to congregate. Consequently, only fish greater than 25 mm in length are counted. Reference specimens and difficult to identify individuals are placed in jars containing 10 percent formaldehyde and later confirmed at the laboratory using taxonomic keys; (Werner 1980; Eddy and Underhill 1983; Smith 1985; Page and Burr 1991; Jenkins and Burkhead 1993). Species particularly difficult to identify are forwarded to fisheries experts outside the Bureau of Freshwater and Biological Monitoring for confirmation (at present the Philadelphia Academy of Natural Sciences).

## MEASUREMENT OF PHYSICAL AND CHEMICAL PARAMETERS

Physical and chemical measurements (e.g. pH, conductivity, temperature, depth) of existing stream conditions are recorded on physical characterization/water quality field data sheets and later summarized.

## HABITAT ASSESSMENT

Habitat assessments are conducted at every sampling site and all information is recorded on field sheets (Barbour et al. 1999). Habitat assessments provide useful information on probable causes of impairment to instream biota when water quality parameters do not indicate a problem. The habitat assessment consists of an evaluation of the following physical features along the 150 meter reach: substrate, channel morphology, stream flow, canopy and stream side cover. Individual parameters within each of these groups are scored and summed to produce a total score, which is assigned a habitat quality category (see Appendix 3).

## QUALITY ASSURANCE/QUALITY CONTROL

A Quality Assurance/Quality Control plan is approved by the DEP Office of Quality Assurance prior to sampling. A copy of this plan is available by contacting the BFBM.

## DESCRIPTION AND DISCUSSION OF THE IBI<sup>2</sup>

Once the fish from each sample collection have been identified, counted, examined for disease and anomalies, and recorded, several biometrics are used to evaluate biological integrity. Fish assemblage analysis is accomplished using a regional modification of the original IBI (Karr 1981), developed by Kurtenbach (1994). Consistent with Karr et al. (1986), a theoretical framework is constructed of several biological metrics that are used to assess a fish assemblage's richness, trophic composition, abundance and condition, and compared to fish assemblages found in regional reference streams<sup>3,4</sup>. The modified IBI (New Jersey version) uses the following ten biometrics: 1) total number of fish species, 2) number of benthic insectivorous species,

<sup>2</sup> Narrative for this section taken largely from Kurtenbach (1994).

<sup>3</sup> For regional reference conditions Kurtenbach (1994) used historical fisheries data collected by the New Jersey Division of Fish, Game and Wildlife (unpublished) at 126 stream sites located in the Delaware, Passaic, and Raritan River watersheds. The fish collection methods and the stream lengths sampled in these historical studies were compatible with Kurtenbach's work.

<sup>4</sup> Trophic guilds, pollution tolerances and origins (native or introduced) of each fish species utilized by Kurtenbach to calculate the IBI were assigned using several fisheries publications (Stiles, 1978; Smith, 1985; Hocutt et al. 1986; Karr et al. 1986; Ohio EPA, 1987; Miller et al. 1988).

3) number of trout and sunfish species, 4) number of intolerant species, 5) proportion of individuals as white suckers, 6) proportion of individuals as generalists (carp, creek chub, goldfish, fathead minnow, green sunfish and banded killifish), 7) proportion of individuals as insectivorous cyprinids, 8) proportion of individuals as trout or proportion of individuals as piscivores (top carnivores) - excluding American eels, 9) number of individuals in the sample and 10) proportion of individuals with disease or anomalies, excluding blackspot disease (see Appendices 1 and 2).

Quantitative scoring criteria were developed for each biometric based upon the degree of deviation; 5 (none to slight), 3 (moderately), and 1 (significantly) from appropriate ecoregional reference conditions. Scores for the individual biometrics at each sampling location are summed to produce a total score, which is then assigned a condition category. The maximum possible IBI score is 50, representing excellent biological integrity. A score of less than 29 indicates a stream has poor biological integrity. 10 is the lowest score a site can receive. Further descriptions of all of the metrics used in the IBI calculations are presented below:

## SPECIES RICHNESS AND COMPOSITION

Four biometrics require the use of Maximum Species Richness (MSR) lines. MSR lines relate species richness to stream size and environmental quality. For streams with drainage areas over 5 square miles in northern New Jersey, species richness is expected to increase with higher environmental quality. Additionally, in a stream with a given level of environmental quality, species richness should increase with stream size. Thus, large sized streams with good water quality should have significantly more species than a small stream with good water quality. MSR lines (See Appendix 3) were developed to show the relationship between species richness and waterbody size in New Jersey. Using the procedure described in Karr et al. (1986), MSR lines for each richness metric were drawn by Kurtenbach (1994) with slopes fit by eye to include 95% of the data points. The area under the MSR line is trisected by two diagonal lines.

Points located near the MSR line represent species richness approaching that expected for an unimpacted stream. Points falling within the lowest trisected area, furthest from the MSR line, represent the greatest deviation from an ecoregional reference condition. For example, using the “total number of fish species” graph in Appendix 3, a sample collection resulting in the capture of five total fish species in a stream with a drainage area of 10 square miles, would receive a score of three and have an intermediate deviation from the expected condition.

### 1. Total number of fish species:

This metric is simply a measure of the total number of fish species identified from a sample collection. A reduction of taxonomic richness may indicate a pollution problem (e.g., organic enrichment, toxicity) and/or physical habitat loss. Fish species with the least tolerance to environmental change, typically are the first to become absent when water degradation occurs. Although freshwater fish species richness in New Jersey is less than half that of the Midwest region where the IBI was first developed (Karr et al. 1986;

Ohio EPA 1987; Lyons 1992), effectiveness of this metric is comparable to regions with richer fish faunas.

## 2. Number of benthic insectivorous species:

This metric is a modification of several metrics used in the original IBI (Karr 1981). Darter and sucker species make up a relatively small component of the New Jersey fish fauna. However, several other benthic species require clean gravel or cobble substrate for reproduction and/or living space. Degradation of this habitat from siltation is often reflected by a loss of benthic species richness (Karr et al. 1986) and abundance (Berkman and Rabeni 1987). Several benthic fish require quiet pool bottoms and may decline when benthic oxygen depletion occurs (Ohio EPA 1987). Further, reductions of some benthic insectivorous fish may indirectly indicate a toxics problem. Benthic macroinvertebrates are an important food source for benthic insectivorous fish and their sessile mode of life make them particularly susceptible to toxicant effects.

## 3. Number of trout and sunfish species:

This metric was adopted as a hybrid for warmwater and coldwater streams. The metric is similar to that used in a combined coldwater-warmwater version of an IBI developed in Ontario (Steedman 1988), but designed for high-gradient rather than low gradient streams. Both sunfish and trout are water-column species sensitive to habitat degradation and loss of instream cover (Gammon et al. 1981; Angermeier 1983). In coldwater streams where sunfish are typically absent, trout fill a similar ecological niche and may be used to replace sunfish. Trout are equally, if not more sensitive to habitat degradation. The relationship between trout populations and habitat is well documented (Peters 1967; Hunt 1969; Meehan 1991).

## 4. Number of intolerant species:

This metric provides a measure of fish species most sensitive to environmental degradation. The absence of some fish species occurs with subtle environmental changes caused by anthropogenic disturbances. Fish species assigned as intolerant should have historical distributions significantly greater than presently occurring populations and be restricted to streams that have exceptional water quality (Karr et al. 1986).

## 5. Proportion of individuals as white suckers:

The white sucker has been chosen to replace green sunfish as a more regionally appropriate tolerant species in the northeast (Miller et al. 1988; Langdon 1992). In New Jersey, the white sucker is commonly found in small and large streams representing a wide range of water quality conditions. White suckers adapt well to changing environmental conditions and often become dominant at disturbed sites. This metric is generally useful in distinguishing moderately and severely impaired conditions.

## TROPHIC COMPOSITION

Trophic composition metrics, unlike the richness metrics, are scored based on a percentage of the total numbers of individual fish captured. The influence of stream size on trophic composition has not been determined for New Jersey streams. However, in Illinois and Wisconsin streams (Karr 1981; Lyons 1992), trophic composition was not strongly influenced by stream size. Based on these findings, fixed scoring criteria are used on all stream sizes found in New Jersey, with the exception of large rivers.

6. Proportion of individuals as generalists (carp, creek chub, goldfish, fathead minnow, green sunfish and banded killifish):

This metric replaces the omnivore metric used in the original IBI (Karr 1981). Use of the omnivore metric was determined to be inappropriate in New Jersey because omnivores are naturally depauperate. Generalists, as defined here, are species with flexible feeding strategies and broad habitat requirements. Often a shift from predominantly specialist groups to generalist groups occurs as water quality becomes degraded (Leonard and Orth 1986; Ohio EPA 1987). Due to broad feeding and habitat requirements, species included for use in this metric are considered tolerant of environmental degradation.

7. Proportion of individuals as insectivorous cyprinids:

Like many streams found in North America, cyprinids are the dominant insectivorous fish in New Jersey (excluding Pineland streams). A shift from specialized invertebrate feeders to generalists with flexible foraging behaviors often indicates poor conditions associated with water quality and/or physical habitat degradation (Karr et al. 1986). Similar to the benthic insectivore metric, insectivorous cyprinids in some instances, may indirectly measure the effects of toxicity.

8. Proportion of individuals as trout or proportion of individuals as piscivores (top carnivores) - excluding American eel (whichever gives higher score):

Streams with slight or moderate water quality impairment generally contain several top predator fish species. In cold water streams of New Jersey, predator fish such as bass and pickerel are depauperate and typically replaced by trout. Thus, a metric is required which measures both groups of top carnivores. A metric fulfilling this requirement is currently used on Vermont streams (Langdon 1992) and has been adopted for use in New Jersey. American eels are excluded from use in this metric. The ubiquity of American eels in streams that have a wide range of water quality and habitat conditions, limits their use as an indicator of aquatic health.

## FISH ABUNDANCE AND CONDITION

### 9. Numbers of individuals in the sample:

This metric measures the abundance of fish captured from a specified area or stream reach and is used to distinguish streams with severe water quality impairment. Like the original IBI (Karr 1981), catch per unit effort is used to score this metric. Severe toxicity and oxygen depletion are examples of perturbations often responsible for extremely low fish abundances.

### 10. Proportion of individuals with disease or anomalies (excluding blackspot disease):

This metric provides a relative measure of the condition of individual fish. Similar to metric nine, this metric is especially useful in distinguishing streams with serious water quality impacts. This metric is intended to detect impacts in streams highly contaminated by chemicals. A significant relationship between the incidence of blackspot disease and environmental quality has not been established for New Jersey streams. As a result, blackspot disease is excluded from use in this metric.

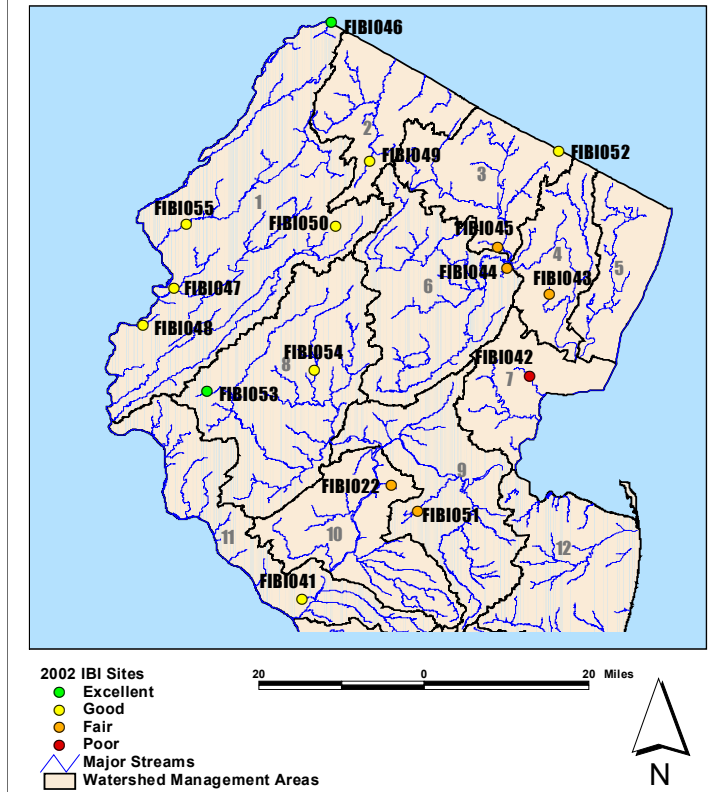


**Multiple fish species from the same stream affected by blackspot disease.**

## RESULTS

In 2002, the third year of sampling, 16 of the 20 planned sites were sampled before the drought forced an early conclusion to the sampling season. Two sites were rated “excellent”, eight were “good”, five were “fair” and one was “poor”.

## 2002 IBI Sites



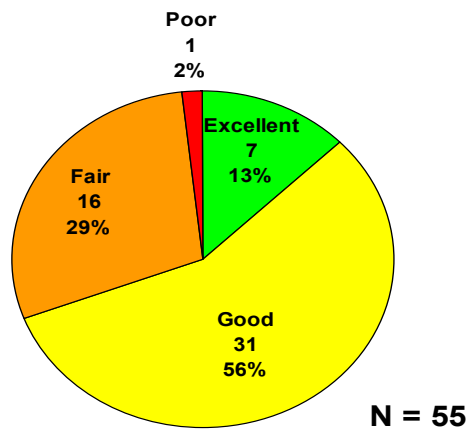
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<sup>2</sup>Sampling maps and data for each site may be found in Volume 2 of this report.

## IBI Ratings - 2000-02



Summary of 1st round IBI ratings to date for 55 sites in northern New Jersey. It is anticipated that approximately 100 sites will be sampled by the end of the 1st Round (Summer 2004).

## **FURTHER INFORMATION**

The current report summarizes the third year of IBI sampling. By summer 2004, the IBI network will have 100 stations in northern New Jersey (an IBI for southern New Jersey is currently being evaluated). Stations will be visited every five years as part of the Bureau's monitoring efforts.

Reports and data for the first three years of the IBI can be obtained on the Bureau of Freshwater and Biological Monitoring's web page: <http://www.state.nj.us/dep/wmm/bfbm> or by calling 609-292-0427.

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# APPENDIX 1

## Revised List of New Jersey Freshwater Fishes

December 2000

	Trophic Guild	Tolerance	Historical Presence
Petromyzontidae:			
American Brook Lamprey ( <i>Lampetra appendix</i> )	NF	IS	N
Sea Lamprey ( <i>Petromyzon marinus</i> )	PF	--	N
Acipenseridae:			
Atlantic Sturgeon ( <i>Acipenser oxyrhynchus</i> )	BI	--	N
Shortnose Sturgeon ( <i>A. brevirostrum</i> )	BI	IS	N
Lepisosteidae:			
Longnose Gar ( <i>Lepisosteus osseus</i> )	P	--	EX
Amiidae:			
Bowfin ( <i>Amia calva</i> )	P	--	NN
Anguillidae:			
American Eel ( <i>Anguilla rostrata</i> )	P	--	N
Clupeidae:			
Blueback Herring ( <i>Alosa aestivalis</i> )	PL	--	N
Hickory Shad ( <i>A. mediocris</i> )	I/P	--	N
Alewife ( <i>A. pseudoharengus</i> )	PL	--	N
American Shad ( <i>A. sapidissima</i> )	PL	--	N
Gizzard Shad ( <i>Dorosoma cepedianum</i> )	O	--	N
Salmonidae:			
Rainbow Trout ( <i>Oncorhynchus mykiss</i> )	I/P	IS	NN
Brown Trout ( <i>Salmo trutta</i> )	I/P	IS	E
Brook Trout ( <i>Salvelinus fontinalis</i> )	I/P	IS	N
Lake Trout ( <i>S. namaycush</i> )	P	--	NN
Osmeridae:			
Rainbow Smelt ( <i>Osmerus mordax</i> )	I	--	N
Umbridae:			
Eastern Mudminnow ( <i>Umbra pygmaea</i> )	I	--	N
Esocidae:			
Redfin Pickerel ( <i>Esox americanus</i> )	P	--	N
Northern Pike ( <i>E. lucius</i> )	P	--	NN
Muskellunge ( <i>E. masquinongy</i> )	P	--	NN
Chain Pickerel ( <i>E. niger</i> )	P	--	N
Cyprinidae:			
Goldfish ( <i>Carassius auratus</i> )	O	--	E
Grass Carp ( <i>Ctenopharyngodon idella</i> )	H	--	E
Satinfin Shiner ( <i>Cyprinella analostana</i> )	I	--	N
Spotfin Shiner ( <i>C. spiloptera</i> )	I	--	N
Common Carp ( <i>Cyprinus carpio</i> )	O	--	E
Cutlips Minnow ( <i>Exoglossum maxillingua</i> )	BI	IS	N
Eastern Silvery Minnow ( <i>Hybognathus regius</i> )	H	--	N
Common Shiner ( <i>Luxilis cornutus</i> )	I	--	N
Golden Shiner ( <i>Notemigonus crysoleucas</i> )	O	--	N
Comely Shiner ( <i>Notropis amoenus</i> )	I	--	N

# APPENDIX 1

	Trophic Guild	Tolerance	Historical Presence
Bridle Shiner ( <i>N. bifrenatus</i> )	I	--	N
Ironcolor Shiner ( <i>N. chalybaeus</i> )	I	--	N
Spottail Shiner ( <i>N. husdonius</i> )	I	--	N
Swallowtail Shiner ( <i>N. procne</i> )	I	--	N
Bluntnose Minnow ( <i>Pimephales notatus</i> )	O	--	NN
Fathead Minnow ( <i>P. promelas</i> )	O	--	NN
Blacknose Dace ( <i>Rhinichthys atratulus</i> )	BI	--	N
Longnose Dace ( <i>R. cataractae</i> )	BI	--	N
Creek Chub ( <i>Semotilus atromaculatus</i> )	I	--	N
Fallfish ( <i>S. corporalis</i> )	I	--	N
Catostomidae:			
White Sucker ( <i>Catostomus commersoni</i> )	BI	--	N
Creek Chubsucker ( <i>Erimyzon oblongus</i> )	BI	--	N
Northern Hog Sucker ( <i>Hypentelium nigricans</i> )	BI	IS	N
Ictaluridae:			
White Catfish ( <i>Ameiurus catus</i> )	I/P	--	N
Black Bullhead ( <i>A. melas</i> )	BI	--	NN
Yellow Bullhead ( <i>A. natalis</i> )	BI	--	N
Brown Bullhead ( <i>A. nebulosus</i> )	BI	--	N
Channel Catfish ( <i>Ictalurus punctatus</i> )	I/P	--	NN
Tadpole Madtom ( <i>Noturus gyrinus</i> )	BI	--	N
Margined Madtom ( <i>N. insignis</i> )	BI	IS	N
Aphredoderidae:			
Pirate Perch ( <i>Aphredoderus sayanus</i> )	I	--	N
Cyprinodontidae:			
Banded Killifish ( <i>Fundulus diaphanus</i> )	I	--	N
Mummichog ( <i>F. heteroclitus</i> )	I	--	N
Poeciliidae:			
Mosquitofish ( <i>Gambusia affinis</i> )	I	--	NN
Eastern Mosquitofish ( <i>G. holbrooki</i> )	I	--	N
Gasterosteidae:			
Fourspine Stickleback ( <i>Apeltes quadracus</i> )	I	--	N
Threespine Stickleback ( <i>Gasterosteus aculeatus</i> )	I	--	N
Ninespine Stickleback ( <i>Pungitius pungitius</i> )	I	--	N
Moronidae:			
White Perch ( <i>Morone americana</i> )	I/P	--	N
Striped Bass ( <i>M. saxatilis</i> )	P	--	N
Centrarchidae:			
Mud Sunfish ( <i>Acantharchus pomotis</i> )	I	--	N
Rock Bass ( <i>Ambloplites rupestris</i> )	I	--	NN
Blackbanded Sunfish ( <i>Enneacanthus chaetodon</i> )	I	--	N
Bluespotted Sunfish ( <i>E. gloriosus</i> )	I	--	N
Banded Sunfish ( <i>E. obesus</i> )	I	--	N
Redbreasted Sunfish ( <i>Lepomis auroitus</i> )	I	--	N
Green Sunfish ( <i>L. cyanellus</i> )	I	--	NN

# APPENDIX 1

	Trophic Guild	Tolerance	Historical Presence
Pumpkinseed ( <i>L. gibbosus</i> )	I	--	N
Bluegill ( <i>L. macrochirus</i> )	I	--	NN
Smallmouth Bass ( <i>Micropterus dolomieu</i> )	I/P	--	NN
Largemouth Bass ( <i>M. salmoides</i> )	P	--	NN
White Crappie ( <i>Pomoxis annularis</i> )	I/P	--	NN
Black Crappie ( <i>P. nigromaculatus</i> )	I/P	--	NN
Percidae:			
Swamp Darter ( <i>Etheostoma fusiforme</i> )	BI	IS	N
Tessellated Darter ( <i>E. olmstedii</i> )	BI	--	N
Yellow Perch ( <i>Perca flavescens</i> )	I/P	--	N
Shield Darter ( <i>Percina peltata</i> )	BI	IS	N
Walleye ( <i>Stizostedion vitreum</i> )	P	IS	NN
Cottidae:			
Slimy Sculpin ( <i>Cottus cognatus</i> )	BI	IS	N

## Abbreviations:

BI	Benthic Insectivore or Invertivore	IS	Intolerant Species
E	Exotic	N	Native
EX	Extirpated (no longer found in NJ)	O	Omnivore
NF	Nonparasitic filterer	P	Piscivore (top carnivore)
PF	Parasitic / Filterer	PL	Planktivore
H	Herbivore	NN	Non Native (introduced)
I	Insectivore		

## APPENDIX 2

### IBI For Northern New Jersey (Metrics and Scoring Criteria) as of 05/03/2000

	SCORING CRITERIA		
	5	3	1
SPECIES RICHNESS AND COMPOSITION:			
1) Total Number of Fish Species	VARIES WITH STREAM SIZE		
2) Number and Identity of benthic insectivorous species	VARIES WITH STREAM SIZE		
3) Number and identity of trout and/or sunfish species	VARIES WITH STREAM SIZE		
4) Number and identity of intolerant species	VARIES WITH STREAM SIZE		
5) Proportion of individuals as white suckers	<10%	10-30%	>30%
TROPHIC COMPOSITION:			
6) Proportion of individuals as generalists (carp, creek chub, goldfish, fathead minnow, green sunfish, banded killifish)	<20%	20-45%	>45%
7) Proportion of individuals as insectivorous cyprinids	>45%	20-45%	<20%
8) Proportion of individuals as trout	>10%	3-10%	<3%
<b>OR</b> (whichever gives better score)			
Proportion of individuals as piscivores (excluding American eel)	>5%	1-5%	<1%
FISH ABUNDANCE AND CONDITION:			
9) Number of individuals in the sample	>250	75-250	<75
10) Proportion of individuals with disease and anomalies (excluding blackspot disease)	<2%	2-5%	>5%

Condition Categories (modified from Karr et al. 1986)

<b>45-50 Excellent</b>	Comparable to the best situations with minimal human disturbance: all regionally expected species for the habitat and stream size, most intolerant forms are present and there is a balanced trophic structure.
<b>37-44 Good</b>	Species richness somewhat below expectation, especially due to the loss of some intolerant species; some species present with less than optimal abundances or size distributions; trophic structure shows some signs of stress (increasing frequency of generalists, white suckers and other tolerant species).
<b>29-36 Fair</b>	Signs of additional deterioration include fewer species, loss of most intolerant species, highly skewed trophic structure (high frequency of generalists, whites suckers and other tolerant species); Trout and/or top carnivores may be rare.
<b>10-28 Poor</b>	Low species richness, dominated by generalists, white suckers or other tolerant species, few (if any) trout or top carnivores, individuals may show signs of disease/parasites and site may have overall low abundance of fish.

## APPENDIX 2

### Species to be included in each of the metrics used by the NJDEP:

**Benthic Insectivores (Metric 2)** – Sturgeon, Cutlips Minnow, Dace, Suckers, Bullheads, Madtoms, Darters and Sculpins

**Trout\* and Sunfish (Metric 3, 8)** – All species in the families Salmonidae and Centrarchidae

**Intolerant Species (Metric 4)** – American Brook Lamprey, Shortnose Sturgeon, All Trout species, Cutlips Minnow, Northern Hog Sucker, Margined Madtom, Swamp Darter, Shield Darter, Walleye and Slimy Sculpin

**Insectivorous Cyprinids (Metric 7)** – All minnows (Family Cyprinidae) in the following genera: *Cyprinella*, *Exoglossum*, *Luxilus*, *Notropis*, *Rhinichthys* and *Semotilus*

**Piscivores (Metric 8)<sup>+</sup>**

\* Streams that have been stocked with trout are sampled during July and August. Both stocked and resident trout found during these months are counted in the IBI scoring. The ability of a stream to support trout during these harsh months (high temperature, low dissolved oxygen) is indicative of good water quality and habitat.

<sup>+</sup>The current form of the New Jersey IBI (Kurtenbach 1994) requires the classification of fish species into trophic categories prior to scoring metric #8. However, many fish species fall into multiple categories as a function of size and life stage. Consequently, the bureau has used available literature (Turner and Kraatz, 1921; Keast and Webb, 1966; Goldstein, 1993), stomach content analysis (Bremer-Faust, 2001; Margolis, unpublished data) and best professional judgement to designate trophic guilds for these species for the 2002 IBI. These designations, which only affect Metric #8, are as follows:

Green Sunfish	Insectivorous
Rock Bass	Insectivorous
Smallmouth Bass	> 90 mm - Piscivorous
Largemouth Bass	> 90 mm - Piscivorous
Yellow Perch	>150 mm - Piscivorous

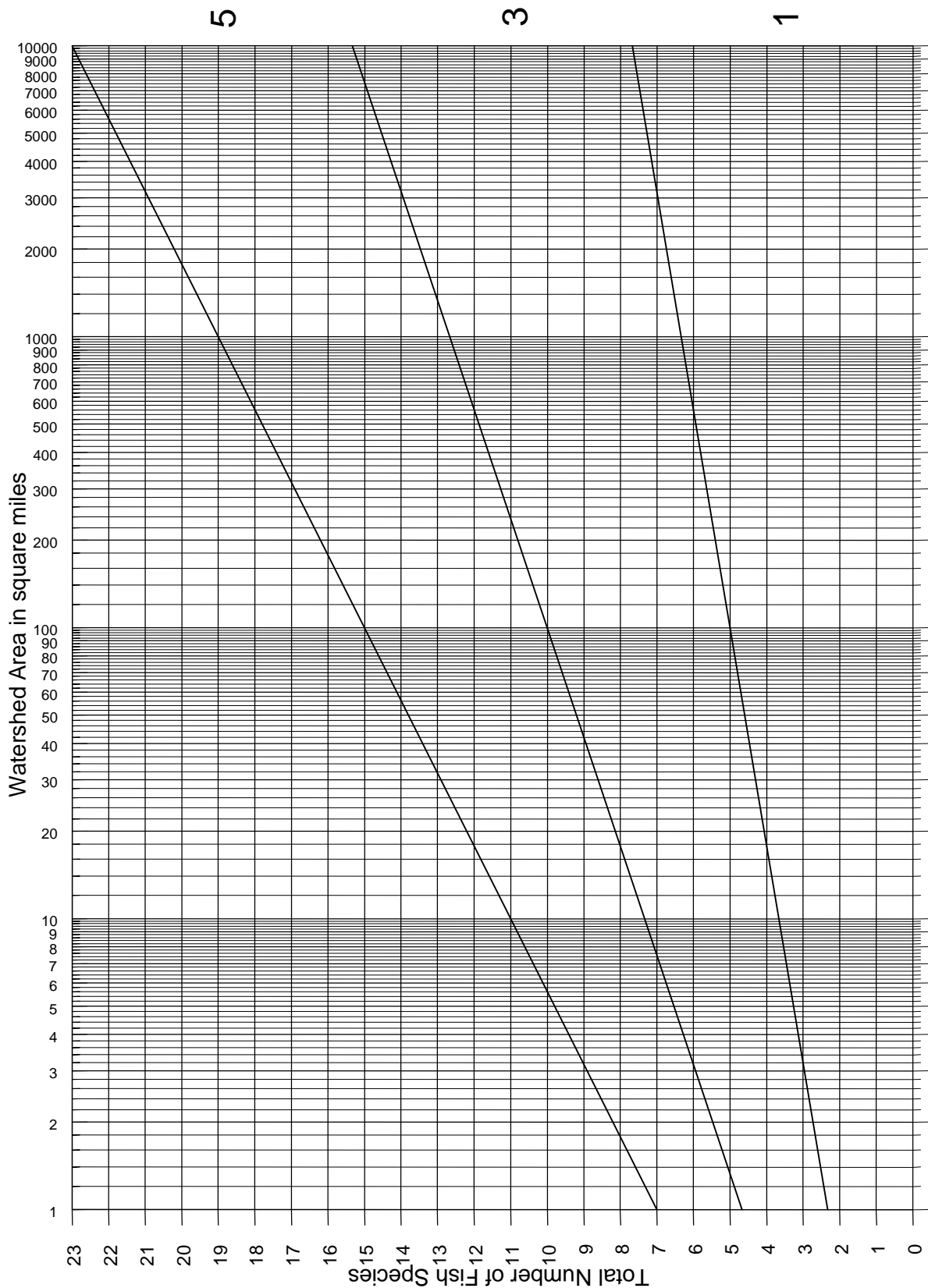
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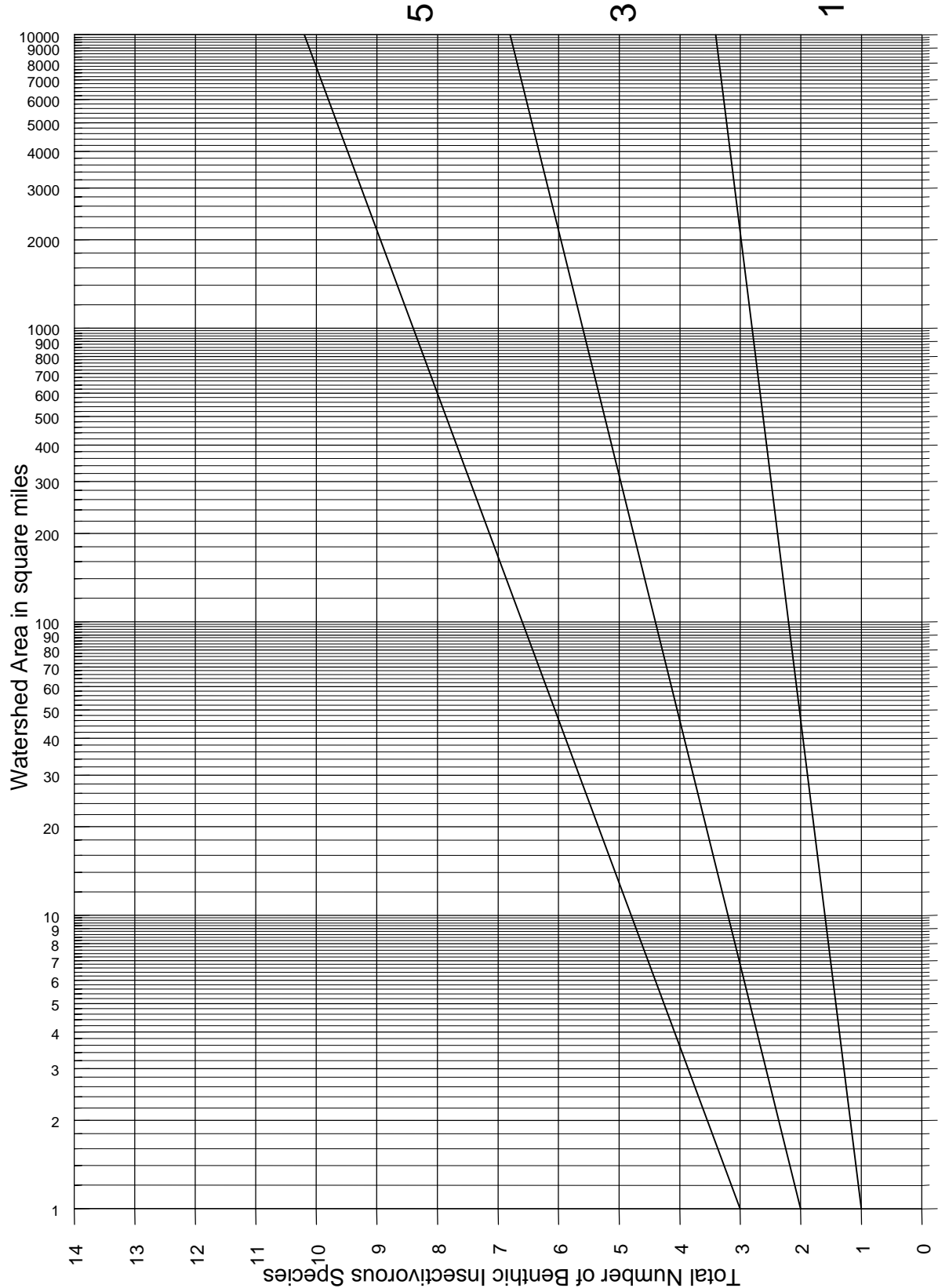
## **APPENDIX 3**

**Maximum Species Richness Lines Used in Scoring Metrics 1-4.**

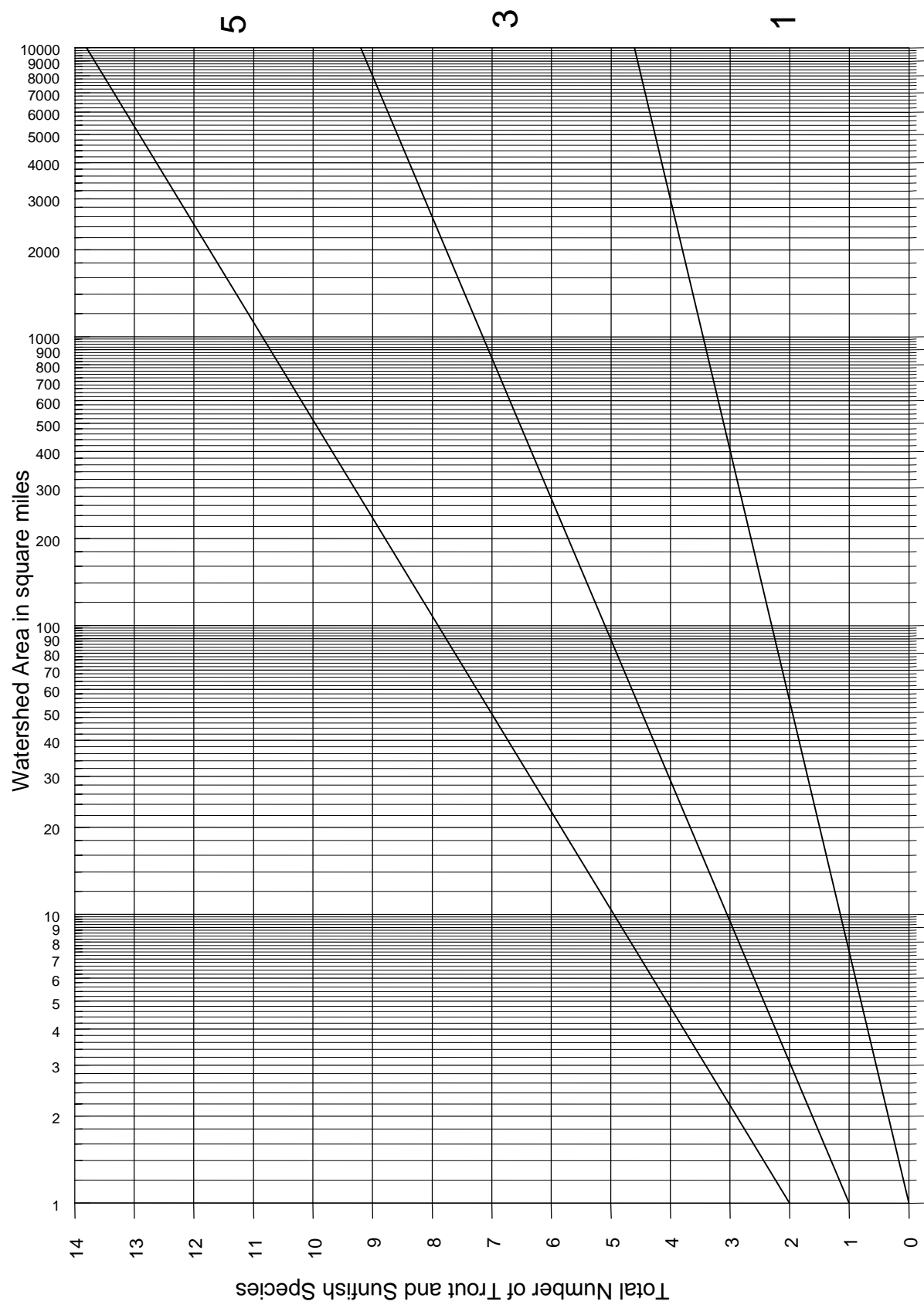
Total number of fish species versus watershed area for New Jersey ecoregion reference sites.



Total number of benthic insectivorous fish species versus watershed area for New Jersey ecoregion reference sites



Total number of trout and sunfish species versus watershed area for New Jersey ecoregion reference sites



Total number of intolerant fish species versus watershed area for New Jersey ecoregion reference sites

